DEPARTMENT OF COMMERCE

BUREAU OF FISHERIES

HUGH M. SMITH, Commissioner

MORTALITY OF FISHES ON THE WEST COAST OF FLORIDA

By HARDEN F. TAYLOR

Scientific Assistant, Bureau of Fisheries

APPENDIX III TO THE REPORT OF THE U. S. COMMISSIONER OF FISHERIES FOR 1917

Bureau of Fisheries Document No. 848

PRICE 5 CENTS

Sold only by the Superintendent of Documents
Government Printing Office, Washington, D. C.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1917

CONTENTS.

MORTALITY OF FISHES ON THE WEST COAST OF FLORIDA.

By Harden F. Taylor, *Scientific Assistant, Bureau of Fisheries.*

OCCASION FOR THE INVESTIGATION.

Repeatedly in the past 75 years reports have come from the west coast of Florida of "poison water," which killed fishes in large numbers, and also, according to some reports, other animals, notably sponges. The reports and references are too fragmentary to give an accurate record of the distribution of the mortality, but collectively they clearly indicate that all the keys from Key West nearly as far north as Cedar Keys have been visited by this plague, and that it occurred in the years 1844, 1854, 1878, 1880, 1882, 1883, 1908, and finally in 1916.

REPORTS OF THE DISASTER IN 1916.

In October and November, 1916, the mortality recurred in severe form, the first visitation since 1908. Numerous descriptive reports were received, from which the following significant points were summarized:

Fishes of a great number of species were noted dead and dying; the air was charged with a suffocating gas, which not only occasioned severe discomfort to man and other air-breathing animals, but irritated the air passages, producing the symptoms of colds. This gas, while exceedingly irritating, had no odor. The fishing smacks which are equipped with "wells" or openings through to the water in which live fish are kept report that the whole catch died while the smacks were en route to port; the normal color of the water had given way to water of different color, variously described as "black streaky," "amber," "olive," and "red"; the white paint of certain houses near the water was temporarily blackened, apparently by gases from the enormous number of dying fish. Some local observers found fish dying in the sounds; others noted them in the passes and in the Gulf to a distance of 45 miles out, but the abundance of fish in any locality varied from day to day. The reports of the order

in which the species appeared are not consistent, so it is assumed that there was no particular succession of species. The abnormal conditions seemed to be moving southward, occurring at Boca Grande on October 3 and 18, at Captiva Pass about the middle of October, at Blind Pass about October 20, at San Carlos Pass about November 1, and dead fish were first seen at Big Marco Pass on November 5. Captiva Pass is 7.5 statute miles south of Boca Grande Pass; the others are, respectively, 16.5, 27.75, and 67.75 miles to the south of Boca Grande Pass. The captain of the steamer *Roamer*, of the Florida Shellfish Commission, reports that dead fish were seen as far south as Cape Romano, about 128 miles south of Boca Grande. The death of two persons in Fort Myers, Fla., in November, was attributed to the eating of some of these dead fish.

The following letters from George H. Skermer, deputy collector of customs at Boca Grande, describing the phenomenon, merit reproduction here. Letter dated October 22, 1916, reads:

I wish to call your attention to an unusual phenomenon which has occurred on the Gulf coast during the past month, and which, so far as I am able to ascertain, has extended on the north to Sarasota and south to Naples, westward, from 15 to 20 miles.

About October 3, large quantities of what are locally known as " red-mouth grunts " began to come ashore. These fish were normal in appearance, with the exception that many showed a tendency to have the eyes almost forced out of their sockets. The early morning of the third the Gulf was covered with these fish as far as the eye could see. Later in the day many other varieties began to drift in, and by night what might be styled windrows of them were lying along the beach. Among them were many fish altogether strange to us; among the known varieties were mackerel, jacks, small shark, porkfish, sheepshead, toadfish (several varieties), mangrove snappers, grouper, sardines, seahorse, cowfish, remora, moray, eels, mullet, pinfish, gurnards, ladyfish, grunts, and many other varieties, not all of which showed the tendency to "popeye."

Soon after this drift commenced I went to the beach accompanied by a small dog; while on the beach I felt a slight tendency to sneeze and cough; shortly afterwards my attention was called to the action of the dog which was sneezing violently and seemed to be in acute distress, choking and showing every symptom of asphyxiation. I carried him off the beach and in a short time he seemed to recover, so I carried him back, and the same thing happened again. I then noticed that my lungs were feeling sore and that my breathing was labored, in much the same manner as when I board ships after fumigation, except that I could notice no odor. Other people were affected the same way.

Later in the day the captain of the Cuban fishing smack *Rafaela Pedre*, which had run into the harbor for water after a 45-day trip, come to the office and told me that his entire catch of grouper and snapper had died almost immediately after the tide started in. I questioned him carefully and found that they had noticed the peculiar sensation I have above described. The next day another smack came in with her fish dead and reported that dead fish covered the Gulf for miles out. The captain of the Dutch steamship *Zeta*, which arrived on the 8th, reported that he had passed through miles of dead fish.

In a few days the plague abated, very few more coming in.

However, on the 18th another violent outbreak occurred, this being much more serious than the first, inasmuch as it had killed many large fish which did not seem to be the case during the first attack. For the past few days the beach has been lined with tarpon, jewfish, grouper, and many varieties of top fish which seemed to escape the first attack. In addition to this, many of the bay fish are succumbing. The gas was very violent this time and many people telephoned for medical assistance for "cold in the head," "sore throats," "cold in the chest," etc., besides coming to see the local physician, who is also the United States quarantine surgeon here. I, myself, have suffered quite acutely for the past five days, but the worst of the gas seems to be going now.

I tried the dog again, and again had to take him off. I do not think he would have been able to live over two hours on the beach. The fish died in a very short time. I observed a mullet dying yesterday; as the tide came into the bayou the gas met him, he began to act strangely, coming to the top, whirling around and around, and then sank to the bottom, lying stomach up for a little while, when he turned on his side dead. Spadefish acted the same way. It is now reported that the fish are dying freely in the remote bays and bayous, every local variety seeming to give up its share. I have been told that many of the barnacles have also died, but I can not confirm this. I have noticed that the conchs and crabs are not dying, at least to any extent. * * *

If you desire any other information as to this matter, I shall be glad to furnish it if it lies in my power. I meant to state that I noticed the pungent feeling of the gas particularly when a wave "broke" and believe that this will explain why the top fish escaped with less visible destruction than the bottom, the breaking of the wave aerating the water more or less. * * *

The gas has none of the characteristics of H_2S; it acts with the same peculiarity of chlorine, but is odorless, perhaps is CO_2; addition of lead acetate to sea water gives a dense white precipitate, but am not sure but that it might do that normally, precipitating lead chloride.

The "odorless but exceedingly irritating gas," as described, was not noted by the observer, but had, perhaps, already subsided. The protrusion of the eyeballs was due to the accumulation of gases from decay behind the orbits, as only those fishes which had been dead for some time were thus affected.

A letter from Mr. Skermer, dated November 11, 1916, reads:

I am in receipt of your letter of the 8th instant relative to the supposed presence in the Gulf waters of *Peridinii* in abnormal numbers. I wish to state that I have not been able to learn of such conditions obtaining nor have I noticed any marine growth of abnormal appearance at any time during the mortality periods. However, I have inquired carefully at every opportunity since the fish began to die from any person who I had reason to suppose had come in contact with the dying fish as to whether he had noticed any peculiarity in the water. I learned from two persons that the fish seemed to die in "streaks" and sometimes in dark-colored water; others noticed nothing abnormal in the appearance of the water but did speak of the odorless but exceedingly irritating gas which seemed to be liberated at intervals. * * *

This morning I inquired of a Spanish fisherman, who lives about 7 miles south of Boca Grande, as to conditions near him. He informed me that fish were still dying along the Captiva Pass and inside waters of Pine Island Sound. He further stated that the fish died when coming in contact with it. The dark-colored water he said was in the bays and did not enter the Gulf at all except at low water. From this I am inclined to believe that it is

simply an overflow of swamp water, and do not believe that it is the cause of the mortality.

The fish were killed many miles out in the Gulf. The captain of the Dutch steamer *Themisto*, which arrived here October 27, told me that he passed through immense numbers of dead fish 45 miles out. I asked him if he noticed anything abnormal in the appearance of the water, and he said "No." A fishing smack which entered here lost all its fish after entering the bay, and another reported that upon attempting to enter the bay saw its fish beginning to die, and that upon turning about and going into the Gulf they recovered. I can only reconcile the two circumstances in this way: For several days after the fish ceased dying in the Gulf they died in the bay, and it is probable that the last-mentioned smack met the returning current from the bay to the Gulf, while the first-mentioned got it in full strength from the Gulf in the beginning of the attack, as he was anchored in the tidal channel. * * *

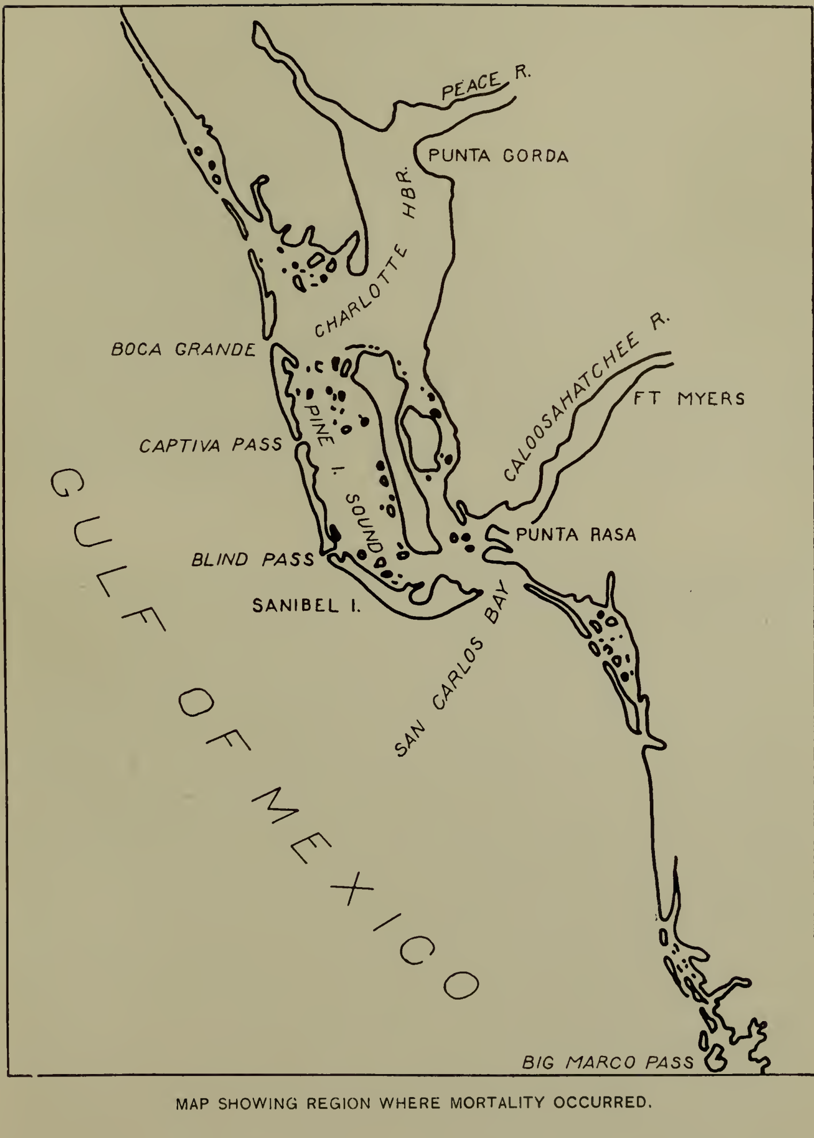
INVESTIGATION IN THE FIELD.

Conditions made it impossible to undertake a field investigation during the early stages of the mortality when it was at its worst, but the writer arrived at Fort Myers, Fla., on the Caloosahatchee River, November 12, and remained in the region for a period of 10 days.

Since the mortality of the fishes had been ascribed to foul water from the Everglades, the condition of this river was first noted. No abnormal conditions were observed in the river; small fish were abundant; birds were feeding upon them. Schools of mullet and red drum ("redfish"), vast numbers of ducks, and many pelicans were seen on the river below Fort Myers. In no case was a dead water animal found on the river. The water was of a brownish color, due, presumably, to tannin or other pigments from the mangroves and palmettoes, but it is understood that such a condition is not unfavorable to fish.

On the next day a reconnoissance trip was made on a river steamer from Fort Myers down the Caloosahatchee to Punta Rasa, thence across San Carlos Bay to Sanibel, across the bay again to St. James City, on Pine Island, thence across Pine Island Sound to Wulfert (inside mouth of Blind Pass), then through a narrow channel to Captiva, returning the same day via Sanibel and Punta Rasa. Between Fort Myers and Punta Rasa (18 miles) the river appeared to be normal in every respect. In San Carlos Bay dead fishes were noted, blanched and soft, apparently having been dead for some time. On the inside beaches of Sanibel, Pine, and Captiva Islands dead fishes in great numbers and of a multitude of species were noted, all in a state of decay.

On the return trip, near Sanibel Wharf, a specimen of squeteague (*Cynoscion nebulosus*) was taken in a state of rigor mortis, but without apparent abnormality.



MAP SHOWING REGION WHERE MORTALITY OCCURRED.

SAN CARLOS BEACH, SANIBEL ISLAND, NOVEMBER 19, 1916.

GULF BEACH, SANIBEL ISLAND, NOVEMBER 19, 1916.

Beginning the next day, November 13, the writer spent three days in the vicinity of San Carlos Bay, with headquarters at Sanibel. In this interval water samples were collected at various places in San Carlos Bay and Pass, Pine Island Sound, Tarpon Bay, and Blind Pass. Efforts made to collect bottom samples were successful only in obtaining pieces of shell and fragments of a thin layer of lime deposit which seems to cover the bottom in San Carlos Bay and Pine Island Sound. Such qualitative tests as were made indicated a rather strong alkalinity. On November 13 and 14 dead fishes were in greater abundance, coming in, apparently, on the tide. On the 13th a census of dead fishes was taken covering 20 steps of the San Carlos Beach, Sanibel Island. This census revealed 163 specimens of fishes, of 26 species, and included neither the windrow cast up at high tide, nor those floating, but only those at or close to the water's edge. On the dark nights of that week the phosphorescence of the decaying fishes made the beach visible for a long distance, and the sand was so charged with phosphorescent bacteria that one's tracks persisted for some seconds. Familiar fishes were identified by their own light. The odor was almost intolerable; people dwelling on the islands hauled away wagonloads and buried them in their orchards for fertilizer.

SPECIES AFFECTED.

In all the region covered the following species were noted:[a]

Species.	Common name.	Family.
Manta birostris[b]	Devilfish	Mantidæ.
Ocyurus chrysurus[b]	Yellow-tail	Lutianidæ.
Neomænis griseus	Mangrove snapper	Do.
Epinephilus morio[b]	Red grouper	Serranidæ.
E. striatus	Nassau grouper	Do.
Garrupa nigrita	Jewfish	Do.
Centropristes striatus	Sea bass	Do.
Menticirrhus sp.[b]	Whiting	Sciænidæ.
Cynoscion nebulosus	Spotted squeteague ("trout")	Do.
C. sp	Squeteague ("trout")	Do.
Bairdiella sp	Sand perch	Do.
Pogonias cromis	Black drum ("drum")	Do.
Sciænops ocellatus	Red drum, channel bass ("redfish")	Do.
Tarpon atlanticus[b]	Tarpon	Elopidæ.
Caranx hippos	Crevallé	Carangidæ.
Caranx crysos	Crevallé ("skip jack")	Do.
Selene vomer	Moonfish	Do.
Trachinotus carolinus	Pompano	Do.
Oligoplites saurus	Leather jacket	Do.
Scorpæna sp	Scorpionfish	Scorpænidæ.
Mugil cephalus	Mullet	Mugilidæ.
Hæmulon plumieri	Grunt	Hæmulidæ.
H. sciurus	do	Do.
Bathystoma rimator	Red-mouth grunt	Do.
Anisotremus virginicus	Porkfish	Do.
Monacanthus sp	Filefish	Monacanthidæ.
Do	do	Do.
Scomberomorus regalis	Cero; kingfish	Scombridæ.
Rissola marginata	Cusk eel	Ophidiidæ.
Scarus vetula	Parrotfish	Scaridæ.

[a] The identifications here represented are, of course, open to question. Time did not admit of careful study. On the great majority of the fishes the colors had faded, of several species only badly decomposed specimens were seen, and some of the others were quite unfamiliar to the observer.
[b] Not seen by writer, but reported by fishermen and others.

87829—17——2

Species.	Common name.	Family.
Chætodipterus faber	Spadefish	Ephippidæ.
Archosargus probatocephalus	Sheepshead	Sparidæ.
Otrynter caprinus	Long-spine porgy	Do.
Calamus sp	Porgy	Do.
Lycodontis (moringa?)	Black moray	Murænidæ.
L. (jordani?)	Spotted moray	Do.
Paralichthys sp	Flounder	Pleuronectidæ.
Echeneis remora	Remora, shark pilot	Echeneididæ.
Clupanodon pseudohispanicus	Sardine ("shiner")	Clupeidæ.
Brevoortia tyrannus	Menhaden	Do.
Chætodon ocellatus	Butterflyfish	Chætodontidæ.
Angelichthys ciliaris	Angelfish	Do.
Lactophrys tricornis	Trunkfish ("cowfish")	Ostraciidæ.
Lactophrys trigonus	Trunkfish	Do.
Prionotus sp	Sea robin	Triglidæ.
Opsanus sp	Toadfish	Batrachoididæ.
Spheroides sp	Puffer ("toadfish")	Tetraodontidæ.
Chilomycterus spinosus	Burr fish	Diodontidæ.
Dasyatis (say?)	Sting ray	Dasyatidæ.
Raja sp	Skate	Rajidæ.
Ætobatus narinari	Spotted sting ray	Myliobatidæ.
Rhinobatus lentiginosus	Guitar fish	Rhinobatidæ.
Felichthys felis	Gaff-topsail catfish	Siluridæ.
Galeichthys (milberti?)	Sea catfish	Do.
Hemirhamphus sp	Halfbeak; needlefish	Hemirhamphidæ.
Tylosurus sp	Marine gar; needlefish	Belonidæ.
	Small eel; whip eel	Moringuidæ?
Leptocephalus conger	Conger eel	Leptocephalidæ.
Synodus fœtens	Lizard fish	Synodontidæ.
Sphyrna tiburo	Shovel-nose shark	Sphyrnidæ.
Carcharinus (obscurus?)	Shark	Galeidæ.
Albula vulpes	Ladyfish	Albulidæ.
Ogcocephalus vespertilio	Batfish	Ogcocephalidæ.

Of invertebrates, sea urchins (*Arbacia*), the king, or horseshoe crab (*Limulus*), and sponges were noted. It is a matter worth noting that very few animals other than fishes were killed. Barnacles, oysters, and mussels were examined, but they were in good condition. Live conchs and hermit crabs were repeatedly observed. Porpoises were plentiful during the period of observation. Pelicans and other water birds behaved normally. Buzzards were common in the locality, yet they neglected the dead fish entirely.

The dead fauna of the Gulf beach was not markedly different from that of the bays. Relatively more carangids, sharks, and rays were seen, but many of the dead forms were buried in the hard beach sand, hence the Gulf beach did not present such a striking picture as did the inside beaches. Taking the whole territory into consideration the relative abundance of the different species is estimated as follows in the order given, less abundant species being omitted:

Grunt (*Hæmulon plumieri*) (*H. sciurus*).
Mullet (*Mugil cephalus*).
Trunkfish (*Lactophrys trigonus*) (*L. tricornis*).
Puffer (*Spheroides* sp.).
Menhaden (*Brevoortia tyrannus*).
Sardine (*Clupanodon pseudohispanicus*).
Red-mouth grunt (*Bathystoma rimator*).
Spadefish (*Chætodipterus faber*).
Moray (*Lycodontis* sp.).
Filefish (*Monacanthus ?*).
Sheepshead (*Archosargus probatocephalus*).
Spotted squeteague (*Cynoscion nebulosus*).

It is assumed that the numbers are representative of the relative abundance of these forms in life. The sizes of specimens would also suggest that all true fishes were killed, regardless of size. They range from jewfish of approximately 200 pounds to forms less than 2 inches long.

METEOROLOGICAL CONDITIONS.

The temperature of the water was around 75° F. until November 15. On this date a violent "northwester" blew up, occasioning a series of extraordinarily high and low tides. After this the temperature was 65° F., and continued at about that figure through the remainder of the observation period. Contrary to what might be expected, the mortality of fishes did not cease after the storm. In this connection it may be added that the wind had been blowing constantly from the northeast for several weeks previously and, after the storm, shifted around to the northeast again.

The water was olivaceous in color—about such a color as would be expected from a mixture of sea water with the brownish water of the rivers. Those accustomed to seeing the water stated that during the period of mortality the water was of a more brownish color than usual. The wake of the boats had an oily appearance, or was apparently not so effervescent as that in normal sea water. It was further stated that at the height of the mortality, on the Gulf coast, the water was of an amber color (by transmitted light). This colored water was described as being not uniformly distributed, but occurring in streaks, and it was in these streaks that the fish are said to have perished. A resident of the island described the death of a mullet thus:

> The fisherman was following a large mullet in Tarpon Bay (partly inclosed in Sanibel Island), intending to capture it with a cast net. The fish, at a depth of possibly 2 feet, seemed suddenly to strike a streak of the bad water, came rapidly to the surface, flipped from the water, and, after a short struggle, expired.

The exact spot, about 6 feet from shore, was visited by the observer, but nothing unusual was noted. Several dead mullets were seen ashore; live porpoises and conchs were in the water.

EXAMINATION OF SPECIMENS.

On November 16 a mangrove snapper (*Neomænis griseus*) was taken by a boatman in a moribund condition. The writer first saw this fish a few minutes after it had died, and he at once dissected it. The blood was not yet coagulated, and, indeed, seemed less inclined to coagulate than one might expect. The fish was not infested with parasites, no lesions were noted, the gills were pink (perhaps too red), the stomach contents were small fish, clean and constituting an

apparently wholesome food. The liver was slightly abnormal in appearance, being faintly mottled with a lighter shade of brown. The mucous covering of the body was transparent and colorless; none of the organs were distended by gas, nor were gas bubbles observed in the blood vessels. The eyes were clear, and no evidence of fungus was seen. The coloring of the fish was vigorous.

Fishes in a moribund condition were reported as having been observed in the passes, in the Gulf, and in Tarpon Bay, but since the carcasses drifted with wind and tide the mere presence of dead fish was not an indication of a mortality at any given place. The condition sought for must have been immediately at hand, however, when a moribund fish was observed on November 19.

It was a small filefish (*Monacanthus* sp.), and was first observed near the dock at Bailey's Wharf, Sanibel, in water not over 3 feet deep. The fish was brilliantly mottled with maroon on a slate-colored background. It was drifting upon its side, making but slight effort to balance. This fish was captured and placed in a bucket of the water from which the fish was taken. A moment later a small, active, pinfish was captured in the same place and likewise kept in another bucket with some of the same water. The color of the filefish faded, but repeatedly revived when the fish was disturbed; each response, however, was weaker than the preceding one until the fish died, and the color faded in about 2 hours. The pinfish, taken at the same time and place, lived till it was released at Fort Myers, about 6 hours later. Both species had repeatedly been noted dead upon the beach. Within 50 feet of the point where the filefish was dying numerous mangrove-snappers and sheepshead were seen, quite healthy in appearance. So we have the anomalous condition of dying fish and perfectly healthy fish within 50 feet of each other and in the same water, with certain knowledge that all the species concerned are subject to destruction by the abnormality responsible for the death of so many species.

Representations were made to the writer concerning the pollution of Peace River. This is a small sluggish stream, tributary to Charlotte Harbor, and drains a region now being worked for phosphate rock. It was said that the waste from the works destroyed the fish. However true this may be, a brief visit only was necessary to show that such a pollution could have no bearing on the mortality under consideration. Small fish as well as vegetation were in the stream; and, besides, the stream is of insignificant size.

DISCUSSION OF POSSIBLE CAUSES OF THIS AND SIMILAR DISASTERS IN OTHER PARTS OF THE WORLD.

It may said at the beginning of this discussion that while a definite conclusion has not been reached as to the cause or causes of this

VIEWS OF SAN CARLOS BEACH, SANIBEL ISLAND, NOVEMBER 19, 1916.

VIEWS OF SAN CARLOS BEACH, SANIBEL ISLAND, NOVEMBER 19, 1916.

mortality, yet certain possible causes are shown not to be operative. Furthermore, significant circumstances in the case of 1916 and of previous years, records of similar disasters in other parts of the world, and opinions of representatives of the numerous sciences concerned, are brought together here as the basis of discussion and also for further work, if there should be a recurrence of the phenomenon.

The mortality occurred in 1844, 1854 (Ingersoll, 1882), and a very severe attack was reported in January, 1878. In August, September, October, and November, 1880, it occurred again, but in relatively milder form. The last two instances are said to have been preceded by earthquakes. In July, 1882, the plague returned; in this case it may be connected with the tilefish disaster, which occurred at the edge of the continental shelf south of Nantucket along the 100-fathom line. In the summer of 1908 a similar mortality destroyed the sponge beds along the keys between Key West and the mainland. In 1916, as above stated, the mortality was exceedingly severe between Boca Grande Pass and Big Marco Pass. The older reports are meager and not based on direct observations; in some cases invertebrates—chiefly sponges and king crabs—were predominant, in others, sharks and porpoises. It may, then, be assumed that the reports furnish no reliable indication of exact conditions.

The causes suggested are (1) water from the Everglades charged with tannin and products of decomposition of palmettoes and mangroves; (2) extraordinary abundance of *Peridinium* known to have occasioned the death of fishes in different parts of the world; (3) a disease, fungoid, parasitic, or bacterial; (4) dilution of the water by unusually heavy rains; (5) an issue of gas, volcanic or natural; and (6) earthquakes or seaquakes.

FOUL WATER FROM THE EVERGLADES.

1. A hypothesis that has been advanced repeatedly is that water from the Everglades, charged with tannin and the products of decay in vegetation, is brought down by the rivers and kills fishes. It may be said with sufficient certainty that this is an impossible explanation. For there are no a priori grounds for assuming that the Everglade water is poisonous; nor is there any material evidence of such a condition. No fresh-water fishes were killed; life in the river was normal; and fishes are known to live in the Everglades. The sporadic appearance of the phenomenon casts doubt on the possibility of such an explanation. And, finally, it seems quite impossible to believe that the volumes of the rivers are sufficient to account for such a widespread distribution of the mortality. It may be, however, that the accumulation of the river load as a decaying organic sediment

furnishes the gases and other products of decomposition confined for a time, but sporadically released by what may be found to be the proximate cause—seismic disturbances. This possibility will be discussed later.

PERIDINIUM AND OTHER PROTISTS.

2. An extraordinary abundance of *Peridinium* has, at times, caused the death of a great number of fish and crustacea. Under certain circumstances, as yet unknown, these organisms multiply in vast numbers, giving the sea a reddish or chocolate color. Such colored areas are usually accompanied by an offensive smell, and are sharply marked off from the unaffected water. They have been encountered by mariners in many parts of the world, and numerous accounts appear in the literature. Darwin (1846) observed it "a degree south of Valparaiso," Nishikawa (1901) and Mitsukuri (1904) on the Japan coast, Carter (1858) around the island of Bombay, Mead (1898) in Narragansett Bay, Smith (1903) in Manila Bay. Both Darwin and Carter cite numerous other references.

Dr. R. E. Coker records (in unpublished notes) from the coast of Peru a phenomenon possibly due to the same cause and commonly known as the "painter." This phenomenon has been described by Hutchinson (1873) thus:

> * * * There is an interesting peculiarity here * * * called the "painter," the palpable evidences of which consist in a changed color of the sea water (most generally to a muddy white), an odor most fœtid, nauseous, and depressing, with the accompaniment of the white paint on ships and boats, inside as well as outside, becoming totally discolored and often partially black. * * * I am induced to attribute this emanation chiefly to submarine volcanic action, generating sulphuretted hydrogen gas. * * * Although met with at Callao, in its most aggravated form, the "painter" is likewise found along the coast as far as San Jose de Lambayeque, nearly 500 miles north. From the end of December until April is the time when the phenomenon mostly exists.
>
> I have before me an analysis of the sea water of Callao, bottled up during the existence of the "painter" and having some mud from the bottom of the bay contained therein. This was sent * * * to London, and was there analyzed by Mr. T. Keates. Mr. Keates reports that, after being allowed to rest, the water poured off proved to be sea water and that the black mud left, after the water had been decanted, was in a state of active decomposition, large quantities of sulphuretted hyrogen gas as well as sulphate [sic] of ammonia being given off. The black color of the mud was found to be owing to the presence of sulphate [sic] of iron which was formed as a result of the decomposition mentioned. Whilst this latter was due to the sulphur of the organic matter combining with the iron present in the mineral part of the mud, to produce the black sulphide [sic] * * *.
>
> 1,000 parts of the mud dried at 230° F. yields:

Water	769.6
Dry mud	230.4

100 parts of the mud dried yielding by analysis:

Organic matter	10.50
Chloride of sodium, alkaline sulphates, etc	6.43
Salts of lime	3.75
Alumina of [and?] oxide of iron [sic]	16.00
Siliceous matter	63.25
Loss	.07

* * * In the course of a few days I observed the water of the bay under four different aspects.

First. Ochre-brown, with somewhat of a reddish tinge, and opaque. This, when examined under the microscope, showed animalculæ of a spheroid or circular form and of like color to the water. In 12 hours after it was—

Second. Of a dark green, and still thick aspect, in which, by the microscope, was visible another class of animalculæ of an hourglass form, round and broad at each end, but contracted at the center. Although there was but one drop of the water under the glass, a large number of these jumped about.

Third. The next morning, or in 14 to 16 hours afterwards, the water was a muddyish white. This time the smell in the harbor was most pungently nauseating. It is considered the true "painter" when white paint becomes black, and headaches are general, with everybody under its influence. No animalculæ were visible through the microscope in this state of affairs from the second to the third condition. I may add that in the intervening period we had a shock of earthquake at about 5 o'clock in the morning, and during the occurrence of which it may be conjectured submarine volcanic action destroyed all animal life of these insects seen two days previously.

Fourth. This is the ordinary water of Callao Bay. * * *

From Hutchinson's description it would appear doubtful that this was *Peridinium.* Darwin's observations (1846) may help to clear this up:

On the coast of Chile, a few leagues north of Concepcion, the *Beagle* one day passed through great bands of muddy water exactly like that of a swollen river; and again, a degree south of Valparaiso, when 50 miles from land, the same appearance was still more extensive. Some of the water placed in a glass was of a pale reddish tint and, examined under a microscope, was seen to swarm with minute animalculæ darting about and often exploding. Their shape is oval and contracted in the middle by a ring of vibrating curved ciliæ. It was, however, very difficult to examine them with care, for almost the instant motion ceased, even while crossing the field of vision, their bodies burst. Sometimes both ends would burst at once, sometimes only one, and a quantity of coarse, brownish granular matter was ejected. The animal an instant before bursting expanded to half again its natural size, and the explosion took place about 15 seconds after the rapid progressive motion had ceased; in a few cases it was preceded for a short interval by a rotatory movement on the longer axis. About two minutes after any number were isolated in a drop of water they thus perished.

This may explain the ephemeral nature of the animalculæ, and also, since they die in such vast numbers, it is not difficult to conceive the consequences of the decay of so much organic matter.

Carter (1858) shows that the various hues of sea water, as described, are due, at least around the Island of Bombay, to one organism, *Peridinium sanguineum.* In the swimming stage the organism is green

and translucent; as the transition time approaches, the chlorophyll-like substance responsible for the green color disappears, a red substance takes its place and dissolves in oil globules that have been forming. At this stage it is red and visible to the naked eye. After only a few days the individuals assemble, lose their red color, become encapsulated (*Protococcus* form), and sink or float on the surface. This stage is followed by a subdivision into two or four new ones. This latter process may be repeated several times until eventually a ciliated form appears again, completing the life cycle. The latter form is covered by an excessively fragile shell which "is broken by the pressure of the thinnest piece of glass."

This description explains the varying color of the streaks, the periodicity, and it may explain the bursting observed by Darwin, if he used cover glasses in observing them.

Could this have been the cause of the trouble in Florida? No evidence of the presence, in extraordinary numbers, of these organisms was found. When the water was described as red, further questioning brought out the fact that it was by transmitted light on the beach, and not by reflected light. Fishes observed while dying were in clear water. Still, the condition as described may have existed before the writer arrived, and the dissolved decomposition gases might have persisted in the water to an extent fatal to fishes after the organisms responsible had perished. Or the organisms might have become lost from view either by disintegration or by passing into the protococcus form and sinking, as suggested by Carter (1858). But such red water, to explain the conditions found, would have to be distributed over an unprecedentedly large area to persist for two months and yet escape detection by the many passing ships, and it would be necessary to explain the widely fluctuating periodicity, in some cases one year, in two other cases 24 and 25 years, respectively.

Gilchrist (1914) definitely ascribes certain instances of mortality on the South African coast to *Noctiluca* and to diatoms. These forms, decaying in large numbers in the water, make the latter an unfit medium for fishes. Among the instances described by him as due to obscure causes, one is clearly due to *Peridinium.*

DISEASE AND PARASITES.

3. Evidence of disease or parasitism is likewise lacking, as is shown by the examination and dissection of specimens already described. On the other hand, it would be difficult to believe, without the most thoroughly convincing evidence, that so many species of animals could be affected by an epidemic of any single disease, or that such

a disease would confine itself to a limited locality for the larger part of a century or perhaps a much longer period of unrecorded observation.

DILUTION OF THE WATER.

4. Dilution of the water hardly deserves serious consideration, for the phenomenon is not correlated with the rainy season or unusual discharge of the rivers. As shown by the table, the salinity does not indicate serious dilution of the water. Of course a dilution adequate to explain the mortality of fishes would concern only an excess of run-off above the normal. The area of ocean concerned, in comparison with the small rivers, at once negatives this hypothesis; and if the water were sufficiently diluted, it may be assumed with good reason that unconfined fishes would seek their proper salinity by migration.

VOLCANIC AND NATURAL GASES.

5. It is now time to call particular attention to certain circumstances of prime importance that have served largely to destroy the foregoing suggested causes, and which can not be overlooked in arriving at a conclusion. They are (*a*) the irregular periodicity, both as to years and seasons; (*b*) the strictly marine aspect of the phenomenon; (*c*) the large area covered; (*d*) the definite limitation of this locality; (*e*) the limitation of the mortality to the animals, whose respiration is performed by an oxygen carrier, hæmoglobin, hæmocyanin, etc.; (*f*) the progressive southward appearance of the mortality.

The irregular periodicity, the marine aspect, the area covered, and particularly the limitation to the region concerned all suggest a geological explanation, whether the issue of a gas or the occurrence of an earthquake, fixed in one place, sporadic in outbreak, and independent of weather fluctuations. The species affected and the southward progress are not contradictory to such an explanation, as will be seen.

Dr. T. W. Vaughan, of the United States Geological Survey, stated verbally to the writer that he saw only the remotest possibility of a volcanic gas in this region. The region is inactive volcanically, and the discovery of a volcanic fumarole would occasion great surprize to geologists. Beyond that we have nothing for or against volcanoes. There is no question that volcanic gases would be deadly to fishes. For, while volcanoes emit different gases in different stages of their activity, the emissions always contain substances deadly to fishes, if nothing worse than carbon dioxide It is scarcely necessary to present data here as to the composition of such gases. Any chlo-

rine, as hydrochloric acid or as ammonium chloride, or in any soluble combination whatever, would certainly be detected by the chlorine determination (salinity); sulphur gases and carbon dioxide would alter the alkalinity of the water, though much would depend on the freshness of the water when the determinations were made. An unfortunate delay impaired the value of the samples collected; it was therefore impossible to determine whether or not these gases were present.

Similar remarks concerning natural gas issues may be made. Such gases consist, of course, largely of the light paraffins, usually small quantities of olefines and occasionally some carbon monoxide. Little is known of the effects of these gases on fish. The injury to man done by methane is done chiefly or entirely by the mere dilution of the air by this gas. Ethylene and ethane probably act in a similar manner. These gases are slightly soluble in water, ethylene to the extent of 4 per cent volume. In water these gases could not act as they do in air, for the solubility of a gas is quite independent of all other gases and as much oxygen would be present in a saturated solution of any of them as in their total absence.

Of carbon monoxide more can be said. This gas acts as a poison to animals, whose respiration is dependent on a blood pigment by combining firmly with the pigment to the exclusion of oxygen; while these animals situated in the presence of abundant oxygen and presenting a wide area of " semipermeable " skin, and whose respiration is performed by the agency of oxygen dissolved in the blood plasma, are immune, since carbon monoxide does not interfere with the passage of oxygen into the body (Leitch, 1916). Carbon monoxide is soluble to a sufficient extent thus to interfere with respiration. It is therefore suggestive to note that all the animals killed, except sponges, were dependent on a blood pigment (hæmoglobin, hæmocyanin, echinochrom, etc.). Sponges are the only animals observed on the beaches whose respiration is not dependent on one of these carriers or pigments, but sponges are often seen, even in normal times on the beaches.

In February and March, 1894, the *Albatross* investigated and reported on a case of widespread mortality of fishes off the coast of California between Santa Barbara and San Diego. Evidences there obtained indicated petroleum and hydrocarbon gases as the cause of the disaster. Many species were killed, but those dead were chiefly flatfish and barracuda. The odor of petroleum was evident from the dead fish. The body slime was colored yellow in patches, and the gall bladder was ruptured. The oil springs said to exist off the coast were held responsible for the oil and gas issues.

EARTHQUAKES.

6. Earthquakes kill fishes directly by concussion. Oldham (1899) cites the case of the destruction of fishes in the Sumesari River in India by the great earthquake of June 12, 1897, which killed "myriads as by the explosion of a dynamite cartridge." Numerous other instances are cited by various authors.

It is not evident in this case from the data at hand that earthquakes killed the fishes directly by concussion. The following extract from a letter from the United States Weather Bureau bears on this point:

> Our records show that during 1916 there were no seismic disturbances of any considerable severity in the Gulf region.
>
> We have no precise earthquake records of that region for the earlier dates, 1844 * * * 1908, but probably no severe ones occurred, as this is not an active seismic region.

Further than this, the long duration of the mortality, the southward progress, and particularly the death of fishes under observation in the partly inclosed shallow water, entirely dismisses the hypothesis of direct injury by shock.

It seems possible, however, that the incidental effects of earthquakes might explain the death of the fishes. For instance, gases are sometimes emitted along with the shock. The following quotation from Darwin pertains to this aspect of the subject:

> In Capt. Fitz Roy's excellent account of the earthquake (Chile, 1833, Jan. 20), it is said that two explosions, one like a column of smoke and another like the blowing of a great whale, were seen in the bay. The water also appeared everywhere to be boiling; and it became black and exhaled a most disagreeable sulphurous smell. These latter circumstances were observed in the Bay of Valparaiso during the earthquake of 1822; they may, I think, be accounted for by the disturbance of the mud at the bottom of the sea containing organic matter in decay. In the Bay of Callao during a calm day I noticed that as the ship dragged her cable over the bottom its course was marked by a line of bubbles.

Prof. J. B. Woodworth, of the Harvard seismographic station, sets forth, in a letter of some length, a possibility which has not been considered, and which seems worth investigating. The substance of his letter is as follows:

Previous to the cases of 1908 and 1916 there are no satisfactory records of seismic activity in the region concerned. It may be quite possible, however, that unobserved shocks of low intensity could explain the mortality; that occluded gases, resulting from the decay of sedimentary organic matter, are released by a disturbance of the sediment, under which circumstances the occluded gases would rise into the water, dissolve, and interfere with the life processes of fishes. Or, at the edge of the rather wide continental shelf in this region, a

seismic disturbance of low intensity might cause accumulated sediments to slide off into abyssal water, similarly releasing occluded gases and also mixing up the mud with the water. It is known that microseisms (as Prof. Woodworth terms them) are radiated from this locality, and it is believed by some that they are due to the West Indian cyclonic storms.

This seems to be the most promising hypothesis. It might be expected that the water flowing into this region carries a large amount of organic matter leached from the abundant Florida vegetation and held in colloidal solution; that this organic matter, on striking sea water heavily charged with lime is flocculated and falls to the bottom on the uncommonly wide expanse of continental shelf in this region; that as it accumulates on the bottom it decays anaerobically, yielding methane, hydrogen sulphide, possibly carbon monoxide, and other gases; that these gases, as generated, are confined by the pressure, increasing sediment, and, perhaps by the limestone crust which appears to cover the bottom; that an earthquake shock, even an unnoticeably mild one, would so disturb the sediment, or break the crust, as to release the occluded gases, and that these gases work, by various physiological and chemical means, the injury to fishes. These organic gases, being rare in sea water, would never be detected by the ordinary analyses.

The work of Prof. J. P. McClendon at Tortugas, in the summer of 1916, suggests that the marginal supply of oxygen in this region is not great. In a letter on the subject he says:

> I think probably lack of oxygen killed the fish. When the P_H of tropical sea water reaches about 7.5 there is no oxygen left in the water. At Tortugas the P_H was about 8.15 and there was about 4 cc. of oxygen per liter.

It would, of course, be necessary to explain any deficiency of oxygen.

ALKALINITY AND SALINITY OF THE WATER.

These two determinations were made as being most likely to reveal any unusual condition of the water. The alkalinity is somewhat higher than that of pure sea water. Dole found this to vary between 0.00237 N and 0.00257 N; McClendon found the alkalinity at Tortugas in 1916 to lie between 0.0023 N and 0.0025 N, while the samples taken in the region under discussion had an alkalinity varying from 0.00236 N to 0.00297 N. This may be explained by the large amount of fresh water flowing into the salt water in this region, which is generally rather strongly alkaline. The salinity is lower than that of pure sea water; this is likewise explained by the fresh water flowing in.

It is noteworthy that the water in which the filefish was seen to die was of the highest salinity and lowest alkalinity found. Otherwise, there seem to be no factors showing any striking correlation.

The following are the results of such determinations as were made:

ALKALINITY AND SALINITY.

Date.	Fraction of normal alkali.	Salinity.	Remarks.
1916.		‰	
Nov. 19	0.00297	29.94	In shallow water at Bailey's wharf, Sanibel, where filefish died.
Nov. 13	.00294	32.81	Sanibel post-office wharf; surface; day before storm; sealed in glass; 76.5° F.
Nov. 16	.00289	31.52	Sanibel post-office wharf; surface; day after storm; 65° F.; very low tide.
Nov. 19	.00288	30.61	Bailey's wharf, Sanibel; 2 fathoms (bottom); 50 feet from point where filefish died; live mangrove snappers.
Nov. 14	.00282	33.93	One-half mile from Point Ybel Light, San Carlos Pass; 75° F.
Do.	.00277	34.20	One and one-half miles from Point Ybel Light, San Carlos Pass; sample from surface; water 2 fathoms; 72.4° F.
Nov. 15	.00277	32.96	Place where mullet died, shallow water of Tarpon Bay; described by fisherman; 1½ hours before storm; 75.3° F.; live conchs; porpoises in water.
Prior to Nov. 13.	.00272	33.10	Specimens submitted by West Coast Fish Co., Kitchins Island, Pine Island Sound.
Nov. 19	.00261	30.97	Bottom (2 fathoms) off Point Ybel Light wharf, Sanibel, 1½ miles from point where filefish died; 65.4° F.
Nov. 15	.00260	32.43	Near Gulf mouth, Blind Pass; rising tide; surface sample; 2½ fathoms water; 20 minutes before storm broke; 75.8° F.; probably pure Gulf water.
Nov. 19	.00236	31.98	Surf water on Gulf Beach.
Mean	.00276	31.56	

OTHER MORTALITIES DUE TO OBSCURE CAUSES.

Other mortalities have occurred in different parts of the world, due to obscure causes. Austin H. Clark (1903) observed a mortality of fishes on the coast of Venezuela, which seems similar to that off the Florida coast. Nordenskiöld (1882) noted dead *Gadus polaris* in the Siberian Polar Sea, which he supposes to have been killed by an insufficiency of oxygen, under the ice, where the fish were confined. Cold has unquestionably brought about the death of fishes in many parts of the world.[a]

Gilchrist (1914) cites numerous mortalities on the South African coast in addition to those already cited, ascribed to *Peridinium*, *Noctiluca*, and diatoms, but altogether without satisfactory explanation. One, however, deserves particular mention. In this case (which repeats itself annually at Knysna) there was a narrow streak of yellowish water extending along the coast for miles, of a temperature about 10° F. lower than the blue ocean water farther out, which was clearly marked off from the yellowish water. The author attempts to explain this by the meeting off this coast of the Mozambique (warm)

[a] On Feb. 2 and 3, 1917, a "freeze" occurred on both coasts of Florida, killing thousands of fishes. This cold wave is described by R. H. Fitch in a forthcoming paper of the Weather Bureau.

and the Antarctic (cold) currents by which the cold water is forced upward along the coast and is limited offshore by the warm current. The periodic nature of the phenomenon is, however, not explained.

This mortality of fishes on the Florida coast may be of interest and importance in many respects. It would hardly be an exaggeration to assert that the number of fishes that perished would be sufficient to supply the State of Florida for a season Yet a few weeks after normal conditions were restored we were informed that fishing on the Florida coast was as good as ever.[a] These facts give rise to the suggestion that, enormous as are the numbers of fishes in our coastal waters, natural causes may be quite as destructive to them as are the activities of man.

The question has arisen repeatedly as to the means by which the strata, rich in fossils of fishes, were laid down. Instances like this and dozens of other in as many parts of the world readily answer the question. Large numbers of decaying animals may also have a bearing on the formation of other mineral beds—the phosphates, for example, that might be produced from the organic phosphorus.

It is also true that, if this misfortune should occur again, valuable information may be gained concerning the presence and number of the various species of fishes, their winter habitat, distribution of sizes, etc., from a study of the dead fishes themselves.

SUMMARY AND CONCLUSIONS.

A mortality of fishes occurred on the coast of Florida from October 3 to the last of November, 1916, appearing progressively southward from Boca Grande to Marco, and apparently killing representatives of all local species of fishes, but very few other aquatic animals, in the sounds inclosed by the keys and in the Gulf of Mexico for a distance of 45 miles or more, but not affecting fresh-water forms. Meteorological conditions were normal. Post-mortems revealed nothing pathological in the fishes. The salinity of the water was somewhat lower than that of normal sea water, and the alkalinity somewhat higher.

The cause of the mortality in this region, as has been stated, has not been determined. Foul water from the Everglades as a possible cause may be dismissed, as well as all meteorological conditions. Volcanic action is highly improbable, and attention need not be turned to such a possibility from the evidence now at hand. *Peridinii* appear to furnish an exceedingly unlikely explanation, but it is, perhaps, proper to reserve judgment, as the evidences contrary to such an explanation are not altogether convincing. A disease

[a] Later reports (April, 1917) from the *Grampus* indicate that the fishing was poor through the winter season.

seems to be a quite impossible explanation. Some geological, perhaps seismological explanation, such as Prof. Woodworth suggests, appears to be the most promising possibility.

Aside from the continued recurrence of the phenomenon in the past, we have no data on which to base a prediction as to future recurrences. In the event of a verification of the seismological-sedimentary hypothesis, a recurrence may be expected sometime. In such an event oceanographic methods should be resorted to at the first indication of the trouble; in the meantime a collection of bottom and water samples over the region is desirable, and, if possible, gas bubbles, if present, should be collected from the mud by appropriate apparatus.

BIBILIOGRAPHY.

CARTER, H. J.

1858. Note on the red coloring of the sea round the shores of the Island of Bombay. Annals and Magazine of Natural History, vol. I, 3d ser., no. 4, art. XXIII, p. 258–262, April, 1858. London.

CLARK, AUSTIN H.

1903. Notes on the habits of certain Venezuelan birds. The Auk, vol. XX, no. 3, July, 1903, p. 285–286. Cambridge.

DARWIN, CHARLES.

1846. Researches into the natural history and geology of the countries visited during the voyage of H. M. S. *Beagle* round the world, under the command of Capt. Fitz Roy, R. N., vol. I, chap. I, journal of Mar. 18, 1832, p. 18–23. New York.

GILCHRIST, J. D. F.

1914. An inquiry into the fluctuations in fish supply on the South African coast. Union of South Africa, Province of the Cape of Good Hope, Marine Biological Report no. II, for the year ending June 30, 1914, art. II, p. 8–35. Cape Town.

HUTCHINSON, THOMAS J.

1873. Two years in Peru, with exploration of its antiquities, vol. I, chap. XI, p. 219–225. London.

INGERSOLL, ERNEST.

1882. On the fish mortality in the Gulf of Mexico. Proceedings of the United States National Museum, vol. IV, for 1881, p. 74–80. Washington.

LEITCH, I.

1916. The function of hæmoglobin in invertebrates, with special reference to *Planorbis* and *Chironomus* larvæ. Journal of Physiology, vol. L, no. 6, p. 370–379. London and Cambridge.

MEAD, A. D.

1898. Peridinium and the "red water" in Narragansett Bay. Science, n. s., vol. VIII, no. 203, p. 707–709. Nov. 18, 1898; Garrison. (Also noted in Report, United States Commissioner of Fish and Fisheries, 1899, p. CXLII.)

MITSUKURI, K.

1904. The culture of marine and fresh-water animals in Japan. Bulletin of the United States Bureau of Fisheries, vol. XXIV, p. 384. Washington.

NISHIKAWA, T.
1901. Gonyaulax and the discolored water of the Bay of Agu. Annotationes Zoologicae Japonenses, vol. v, pt. I, p. 31. Tokyo.

NORDENSKIÖLD, A. E.
1882. The voyage of the *Vega* round Asia and Europe, with a historical review of previous journeys along the north coast of the Old World. Translated by Alexander Leslie, p. 246–247. New York.

OLDHAM, R. D.
1899. Report on the great Indian earthquake of June 12, 1897. Memoirs of the Geological Survey of India, vol. XXIX, p. 80. Calcutta.

SMITH, HUGH M.
1903. Peridinium. (Editorial article containing an extended quotation from Dr. Smith.) Philippine Journal of Science, vol. III, no. 3, p. 187. Manila.

TANNER, Z. L.
1896. Report upon the operations of the United States Fish Commission steamer *Albatross* for the year ending June 30, 1894. Report of the Commissioner for the year ending June 30, 1894, p. 217–218. Washington.

Brief notes have appeared in the publications of the Bureau of Fisheries in previous years as follows: Rathbun, Richard (Fisheries and Fishery Industries, sec. V, vol. II, p. 831). Newspaper clipping (Bulletin, vol. II, 1882, p. 104). H. D. Pierce (letter, Bulletin, vol. IV, 1884, p. 264). Smith, H. M. (Bulletin, vol. XVII, 1897, p. 234.) Moore, H. F. (Bulletin, vol. XXVIII, pt. I, 1908, p. 434). Report for 1886 (p. 68–72).

O